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High-strength, high-performance, turbine design
for high power-density applications

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Abstract

Supersonic turbines are frequently used when significant amounts of power must be extracted from a small amount of mass flow subject to large pressure drops. Applications for such turbines range from compact underwater propulsion systems to liquid propellant rocket engines. The latter application is of particular importance in human rated upper stage engines to be used in Space Exploration missions. Historically, R&D efforts in this area have focused on reducing the stresses associated with unsteady aerodynamic forces on the airfoils. Center-bore straight nozzles have been replaced with two-dimensional wrapped airfoils, and more recently with innovative three-dimensional airfoil designs. While these new designs reduce the unsteady aerodynamic loads, the thin profiles that these airfoils exhibit towards the trailing edge introduce stress and manufacturability issues. A new design approach based on neural networks has been employed here to overcome such shortcomings and obtain significantly stronger and robust airfoils while maintaining and even improving the aerodynamic performance. A representative application consisting of a one stage supersonic turbine with a Mach number of 1.5 at nozzle discharge is presented here. The redesigned supersonic vane is stronger than the baseline, has slightly lower losses, and an improved surface pressure distribution. The redesigned vane also exhibits smaller tangential variations of flow velocity at the exit of the vane. This feature indicates reduced stator/rotor interaction effects. Isolated nozzle row and full stage performance data will be presented.

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³ NASA Ames Research Center has filed patent applications focused on methods of producing subsonic and supersonic turbine vanes and the particular supersonic vane and variants thereof that are discussed in this paper. A patent for the underlying neural network design methodology has been granted.

